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# Reassessment of laboratory work

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**Abstract**

Before World War II, laboratory work was one of the critical components in engineering education where students experienced learning practically. It has undergone major changes since the war where basic knowledge has become extremely important to enable engineers to solve new problems innovatively. Consequently, the role of laboratory work becomes less important and is often taken lightly. Students are also of the opinion that laboratory work is burdensome and is not beneficial to them. The practice of students copying past year's laboratory reports has become an issue which is often discussed. Feedback from employers reveals that graduates lack the ability to relate laboratory work to the real world. This paper presents recommendations on how to solve the problem by looking at laboratory work from the Problem Based Learning approach where students are given an actual problem to solve using several laboratory tests. This approach has motivated students to see and realize the link between laboratory work and actual engineering problems.



*Keywords:* Outcome based learning; linking basic courses with engineering

## 1. Introduction

Laboratory work is part of the requirements of the Board of Engineering Accreditation Council (EAC). Traditionally, engineering students are given a detailed manual for each laboratory assignment to be carried out. Specific details on how data is observed, analyzed and interpreted are then explained to the students. In short, students just follow instructions and finally they are required to submit their reports. Often in such a situation, students do not show high level of interest. They view laboratory work as burdensome as they cannot see the link between the work done at the laboratory with actual problems (Rivarola and Garcia, 2000).

## 2. Past And Present Laboratory Work

Before the 18th century, engineering training was not conducted at the university, but was learned as on-the-job training. In 1802, the first engineering institution of higher learning in the United States was established to train military engineers. At that time, engineering training was still done through practical training in the laboratory. This

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method continued to be used until World War II. After the war, many inventions and new discoveries were produced by individuals trained as scientists, rather than engineers. As a result, engineering educators had to review the engineering curriculum and included basic courses such as mathematics, physics and chemistry so that engineers could identify the basic problems. Because of that, the role of laboratory in engineering education became less significant. After the landing of man on the moon and also the end of the Vietnam War, the United States government cut the funding for engineering education in the 1970s, resulting in engineering faculties there significantly reducing the amount of laboratory work in their courses (Feisel and Rosa, 2005).

Nevertheless, the industry needed engineers who not only knew the theoretical aspects, but also could understand practical situations. With this in mind, in 2000 the United States' Accreditation Board for Engineering and Technology (ABET) came up with a new accreditation method which let the universities determine their own learning outcomes and measurements. One of the learning outcomes required is the ability to design and conduct experiments as well as to analyze and interpret data (ASCE, 2004). This clearly shows the need for laboratory work which has to be conducted by students themselves including the ability to observe, analyze and interpret data.

The Malaysian Board of Engineers' Engineering Accreditation Council (EAC) has long included the above outcome as one of the requirements that Malaysian graduates must have. Thus, laboratory work has to be included to ensure that students can achieve the outcome.

## 3. Potential Of Laboratory Work

When we look back at the original roles of laboratory work before World War II, we would realize its huge potential. Among the attributes that can be instilled into students through properly conducted laboratory work are:

- Ability to work in groups
- Ability to choose and use appropriate instruments
- Ability to design experiments
- Ability to observe, analyze and interpret data
- Ability to construct and design models using observed data
- Ability to have deeper understanding of the real world through experiments
- Awareness on the need for lifelong learning

### *3.1 Ability to Work in Groups*

The ability to work in groups is one of the most essential qualities for an engineer. It has become a critical criterion for large companies when hiring staff. Laboratory work is normally done in groups. A group can be an effective team if the selection of team members is carefully done. If students are allowed to choose their own group, the good ones would choose to team up with other good students, and the weak ones would end up with other weak students. The weak students would work helplessly and further reinforce their misunderstanding. On the other hand, the good ones would prefer to work on their own and spend great amount of time settling their differences in opinion (Oakley et al., 2004).

### *3.2 Ability to Choose and Use Appropriate Instruments*

In today's practice, students are given a detailed work manual and a demonstrator showing the step-by-step methods of the laboratory work. This would not develop students' ability in terms of instrumentation. Students would be able to learn actively if they are given the problem and objective and then left to their own devices. The weak students would be guided by the good ones while the good ones would gain a better understanding by teaching the weak students (Felder and Brent, 2003).

### *3.3 Ability to Design Experiments*

The practice of giving students experiments one after another, complete with the manuals and detailed demonstrations will not train them to design experiments as they are just following instructions. Instead, if they are

given a problem which requires them to obtain several parameters and tests without telling them which experiments to be done, this would train them to design their own experiments. From experience, it has shown that they may encounter some difficulty at first and may not be able to see the directions they are heading. However, after a while and after discussing with other good students, they are able to see what they are supposed to do. Such cooperative learning often occurs when they are in groups (Haller et al., 2000).

### *3.4 Ability to Observe, Analyze and Interpret Data*

If students are given an experiment and are told which data to be observed, which method of analysis to be used and how to analyze it, they would just follow instructions. However, if students are given a problem which requires them to observe data at certain locations, analyze the data as well as interpreting it in order to find a solution, they would be able to apply the same strategy to solve other problems.

### *3.5 Ability to Construct and Calibrate a Model using Observed Data*

Developing models has become an essential instrument in engineering to predict results. Nevertheless, undergraduate students have not been getting adequate exposure in this area. The fact is that they have been exposed to modelling indirectly in their laboratory work when they compare the observed data with the one generated using mathematical formulas. Such practice needs to be modified so that students are trained to see the pattern from the observed data and then find the appropriate mathematical formula that matches it before calibrating it.

### *3.6 Ability to have deeper understanding of the real world through experiments*

Among the feedback received from civil engineering employers invited to provide advice and recommendations on the curriculum is that engineers lack the skill to link laboratory tests with the real world. This shows that there is a shortcoming in the implementation of laboratory work in engineering courses. If laboratory work is properly carried out, students should be able to estimate the strength of a slope and its collapse mechanism by conducting a direct shear test on the soil sample taken from the foot of the slope. They would also know how to choose and measure the correct parameters in order to get the solution to the problem.

### *3.7 Awareness On The Need For Lifelong Learning*

Many large companies nowadays place great emphasis on the strong desire to acquire knowledge as one of the requirements when hiring new engineers to ensure that their companies are always ahead in their area of specialization. Hence, students have to be trained to have a hunger for knowledge, and this can be done through laboratory work. Students should only be given brief instructions and are required to obtain additional information such as the theoretical knowledge and methods on their own. By doing it this way, they would familiarize themselves with self-learning which forms the basis for lifelong learning.

## 4. Recommendations

Laboratory work consists of activities which are costly and take up a great deal of students' time. Thus, it has to be optimally used so that it can become a learning experience which brings a lot of benefit to students. To achieve this, the following have been recommended:

- The aims of each laboratory assignment have to be made clear to lecturers as well as students.
- Students need to be given actual engineering problems that can be solved by conducting several laboratory tests and experiments so that they can see not only the link between laboratory work and the real world but also gain a better understanding of the problem in the real world.
- Based on the problem given, students have to determine the equipment, test and experiment to be done so as to train them to design their own experiments.
- From the given problem also, students need to ascertain the data to be observed, analyzed and interpreted.

- Based on the data observed, students have to obtain the appropriate formula and calibrate it so that students have the ability to develop the right models.

## 5. Conclusion

Before World War II, laboratory work was the essence to engineering education where students were trained practically. While most new discoveries after the war were made by scientists instead of engineers, engineering education had to be reviewed and a great deal of knowledge on basic science and mathematics was incorporated in the curriculum, resulting in laboratory work becoming less significant. However, it can be meaningful if it is treated as actual problem solving activity. Students are therefore required to fully understand engineering problems and develop appropriate models apart from equipping them with the skills set by the accreditation board.

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